University of Alberta Library
0 1620 2762234 7

Bulletin No. 17 (Third Edition). *Revised March, 1938.*

UNIVERSITY OF ALBERTA
COLLEGE OF AGRICULTURE

Some Power Problems of the Farm

BY

J. MACGREGOR SMITH
Department of Agricultural Engineering

Distributed by
Department of Extension, University of Alberta
Edmonton, Alberta, Canada

EX LIBRIS
UNIVERSITATIS
ALBERTENSIS

Prairie Provinces Collection

Bulletin No. 17 (Third Edition). *Revised March, 1938.*

UNIVERSITY OF ALBERTA
COLLEGE OF AGRICULTURE

Some Power Problems of the Farm

BY

J. MACGREGOR SMITH
Department of Agricultural Engineering

Distributed by
Department of Extension, University of Alberta
Edmonton, Alberta, Canada

COMMITTEE ON AGRICULTURAL EXTENSION AND PUBLICATIONS

W. A. R. KERR, M.A., Ph.D., LL.D., Chev. Leg. d'H., O.I.P., F.R.S.C., President of the University, Chairman.

E. A. HOWES, B.S.A., D.Sc., Dean of the Faculty of Agriculture, Vice-Chairman.

F. A. WYATT, B.S.A., M.S., Ph.D., Professor of Soils.

J. MACGREGOR SMITH, B.S.A., Professor of Agricultural Engineering.

J. P. SACKVILLE, B.S.A., M.S., Professor of Animal Husbandry.

E. H. STRICKLAND, M.Sc., Professor of Entomology.

J. S. SHOEMAKER, B.S.A., M.Sc., Ph.D., Professor of Horticulture

K. W. NEATBY, B.S.A., M.S.A., Ph.D., Professor of Field Crops.

H. R. THORNTON, B.Sc., Ph.D., Professor of Dairying.

DONALD CAMERON, M.Sc., Acting Director, Department of Extension, Secretary.

CONTENTS

	Pages
Power Farming	5-9
Horsepower	9-13
Brake Horsepower	14-16
Drawbar Horsepower	17-19
Tractor Tests	20
Sizes and Speeds of Pulleys	20-27
Belt Lacing	28-38

PREFACE

Many requests have come to this department for information along the lines of that contained in this bulletin.

In 1928 the first edition of this bulletin was published. Great changes have taken place throughout the world during the intervening period of three years and the changes since that time are even greater. However, there is little change in connection with the statement made at that time, but there are one or two points that should be emphasized. There is a great deal of loose talk about mechanized farming, and one must realize that farming by power does not necessarily imply farms extending to thousands of acres. A diversified dairy farm of the most intensive type may very well use a general purpose tractor. The point is that each man must decide for himself what type of power he should use. The use of power is neither a panacea for all the ills of agriculture, nor is it the cause of them.

Do not be carried away by high pressure salesmen. Think carefully before buying, and then you will have no regrets. "Be not the first by whom the new is tried, nor yet the last to cast the old aside," is a timely suggestion. Unless a very substantial cash payment can be made on any piece of equipment it is a much wiser policy to postpone the purchase of it.

Some new material has been added dealing with the Nebraska Tractor Tests and the methods of interpreting the data on the horsepower developed and the fuel consumption. It is most important before buying a tractor to think the matter over carefully and have clearly in mind what may be reasonably expected from it in terms of hours of work per year and its capacity both on the belt work and at the drawbar.

The second edition was published in 1931 and the foregoing observations seem to be just as timely now as then. The use of the modern tractor is decidedly on the upward trend. In western Canada 7385 new tractors were reported sold in 1937 (2260 in Alberta), and this year will, in all probability, show a large increase. (27.6 per cent. of the total were equipped with pneumatic tires.) In Great Britain the use of power is on the increase and the latest estimate places the number of tractors in use at 46,000.

It is hoped that the contents of this bulletin may be of some assistance to those interested in the application of mechanical power to agriculture in its many and varied branches.—J.M.S.

Some Power Problems of the Farm

BY

J. MACGREGOR SMITH

Department of Agricultural Engineering

There is a great interest at the present time in the question of Power Farming. Therefore it might be advisable at this time to discuss briefly the subject in a general way in the hope that it may help some to decide for or against it.

Agricultural leadership on the North American Continent depends upon the increasing and continued use of up-to-date labour saving equipment. The present agricultural supremacy both in production per man, and standards of rural living, has been attained to a great extent by the use of improved machinery. It is well to remember that many of our greatest competitors have awakened to this vital fact.

When Mr. W. M. Jardine was secretary of Agriculture at Washington, D.C., he made the following statement:—

"The most impressive development of all time in agriculture has been the advent of modern farm machinery. I wish I might have the time to paint for you gentlemen something of the picture of revolution that American farm machinery has wrought in crop production. Could the farmer of Pharaoh's time have been suddenly reincarnated and set down in our grandfather's wheat fields, he could have picked up the grain cradle and gone to work, with a familiar tool, at a perfectly familiar job. And then, within the space of twenty years, the methods of crop production underwent greater changes than they had in the previous 5,000 years. At one stride we covered ground where fifty centuries had left almost no mark of progress whatever. Suffice to say that between 1880 and 1900 our production per worker engaged in agriculture rose about 25 per cent., and the total output of farm products increased nearly 70 per cent.

During the war period, again, agriculture came under this great pressure for increased production. Rising prices, patriotism, government activities all combined to stimulate it and the development of the gasoline motor and improved machinery helped to make it possible. Thus, between 1910 and 1920 crop production per agricultural worker was further increased by 18 per cent., or nearly a fifth."

It must be remembered, of course, that power farming is a wide subject, and like every other farm problem in the last analysis its solution rests with

the individual farmer. It makes little difference if it be a question of the location of the farm buildings, the type of farming in which to engage, or the class of livestock to be carried, because in the end the individual is responsible for his decision. He has to study the facts in an unbiased way.

The use of a tractor for power on the drawbar or the belt does not mean necessarily the total elimination of all livestock from the farm. There are cowless, sowless, and henless farms where only horses are used for power. There are extreme cases on both sides of any question. People today are living in a mechanical age and want to do their work in the easiest way, which may or may not be the cheapest, and there is no use trying to convince them to the contrary. If it is true that Agriculture is the foundation of all our social and industrial life, then must the plow be given credit for having made agriculture possible. All the modern complex life today has followed in the furrow of the plow, and in Western Canada in the last thirty years tractors have pulled more breaking plows than some may realize.

The success of a country dates from the time the first sod was turned, and today the United States, with its 6,000,0000 farms, is using approximately 1,500,000 tractors. These tractors are pulling all kinds of machinery, including even four row corn planters, which must be operated with the greatest accuracy if a good "check" is to be obtained. It is agreed that tractors can neither raise colts nor make manure, and therefore there is no use wasting time in arguing that the lack of either quality is a weakness. It is also known that horses cannot work efficiently at their rated power for over ten hours, while the tractor with a good operator on the seat can run for twenty-four hours a day if necessary. The horse can develop a large over-load for short distances, and thus get through a tough place when necessary. If a man decides to use a tractor and is a good farmer he will have the stock to produce the necessary manure to keep up the fertility of his land, so that the first contention still stands, namely That the method of operating any individual farm depends upon the personality of the man running it. A man who does not like a tractor will not be satisfied with his purchase any more than a Clydesdale man would be satisfied to use Percheron horses, or a farmer from the corn belt with its lard type of hog would feed successfully a bacon hog.

No matter whether the tractor or the horse is favored, it must be borne in mind that farms and farm methods are changing due to the tractor's entrance into farm life. Many farmers are well satisfied with tractors and, more than one would imagine, haul their grain to town in motor trucks and are very decided on the advantages of this method of transportation. The times are changing and tractor operated farms are not alone in this change. Farms, where horses are used exclusively, are also changing their methods. The type of farm horse is changing, larger horses and larger teams are used in larger power units on larger machines. Why?—because people realize that an increase in profit per acre must come by lowering

the cost of production per acre, by using every possible method that means greater efficiency in farm management. The vital importance of getting work done at the right time is something that is too often overlooked. At seed time and harvest this is particularly true. The success of power farming depends upon three main factors. These make a chain and every link must be sound if the chain is to stand the strain—Manufacturer, Distributor, and the Purchaser or Operator

1. Manufacturer.

There is no doubt that the manufacturer of the successful tractor today is building a reliable power unit, and to classify as such, efficient distribution and service must be taken into account. Manufacturers can build a tractor from the best material and put into the finished machine:—

A strong frame.

A good motor, efficient in every way.

A good lubrication system.

A good ignition system,

and then mount the various units on four good wheels. But on the seat there must be a capable operator if satisfaction is to follow. Anyone can sit on a sack of hay on a comfortable spring seat and steer and stop the tractor, but skill is required to start it whenever necessary and to keep it going continuously.

2. Distributor.

The dealer ought to bear in mind the necessity of telling the customers the truth and the actual facts about the machine he wishes to sell. It is his duty to make himself acquainted with the prospect's problems and to advise him in a wise and conservative way. Machinery of all kinds must stay sold after it has been formally paid for, either wholly or in part. This means real satisfaction.

The Service School.

There are two ways to learn how to do a thing. One is to rack one's brain and then by cut-and-try methods develop something to fit the case. The other way is to watch the trained expert, and then do likewise. The investment required for the expenses of going to a tractor school, will give a good percentage in return. Because an operator will be able to save time and money from the knowledge gained, and may learn that he was never intended to own or operate a tractor; in either case he is the gainer. Life is too short and time is too valuable to permit learning everything at first hand. This is the reason why there are tractor schools. Anyone owning or contemplating the purchase of a tractor will be well repaid for any sacrifice made to spend some time at such a school.

3. Purchaser.

He has to consider the following points amongst others:—

1. Mechanical Design.
2. Simplicity.
3. Accessibility of parts that have to be replaced and adjusted more or less frequently.
4. Lubrication.
5. Protection of working parts from dust.
6. Adaptability to special conditions, size, weight, type, etc.

The standing of the Company manufacturing the tractor should be investigated, as it has an important bearing upon the likelihood of securing repair parts. It also insures the purchaser against loss in case a defective machine is purchased.

In Western Canada thirty years ago an automobile did well to travel at the tremendous rate of twenty miles per hour, and although it got there, it was always uncertain whether or not it would get back without the aid of a team. Today the first question a man asks when he buys a car is not "How long will it last?"—but, "How fast will it go?" And so it may be well for the man who contemplates power farming to think in terms of the amount of work done in a given time. It is agreed by many that mixed or diversified farming is the only safe kind in which to engage. A man might reason this way. Would it pay to milk a few cows and feed a few pigs morning and evening, and then take a tractor and work six or seven hours in the field putting in the crop in better time and probably with the seed bed in better condition than could possibly have been done with horses? This is one of the many possible problems that the individual has to decide. Many tractor surveys have been made, but space does not allow the discussion of them in detail.

Think of harvesting with the cradle and binding by hand! Think of the modern 10-foot binder driven by a power take-off, and think of the evident possibilities of the Combine Harvester in certain areas, and then sit down and think of what the future years may bring forth and what all these things will mean to agriculture in Alberta.

To get a clearer perspective of Power Farming as it exists today, not only must present conditions be considered, but past progress and accomplishments. It is only about 35 years ago since the first gasoline tractors were produced commercially. The automobile at that time was a rich man's plaything because of its high initial cost, higher upkeep and general unreliability. Compared with our conception of a good car today, it was at that time an utter impossibility. There were no antifriction bearings, no reliable ignition systems, no accurate carburetors, no good lubricating systems or even lubricants, no service for fuel, oils or repairs. In fact, there were none of these things which are looked upon today as essential to the

successful production and operation of an automobile. Today every garage and service station displays the sign, "Free Air," and before long very few people will know what a tire pump looks like, and will have to go to a museum to see one. There have been tractors that were too big and heavy; one wheel tractors, two wheel tractors, three wheel tractors, four wheel tractors; crawling tractors and walking tractors; some with plows in front and some with them underneath, and in fact with "features" (spelled in large letters) too numerous to mention.

But during the past thirty years a few have survived the struggle, and the tractor of today, which is manufactured and sold by a reliable company, is an efficient machine and is giving good satisfaction.

Doubting Thomases predicted failure for the Automobile, and yet today it has converted practically every livery stable into a garage, and motor cars and tractors are crossing the Sahara desert and the snow fields of the North. Through the use of the automobile people have become acquainted with the operation and care of the internal combustion engine.

In conclusion, a story, which is well worth while, might emphasize the point.

In spite of the fact that Mr. Henry Ford has been building large aeroplanes for carrying freight and passengers for several years, it is reported that he never ventured up in one himself until Lindbergh had flown the Atlantic Ocean and had returned safely from his triumphant tour of the United States. After his return with the flying ace of world renown, Mr. Ford said, "Well after all, its 90% man and 10% machine." This story can well be applied to the application of power farming to agriculture. There are sufficient reliable machines, which will be improved from time to time. Before making the final decision the question to ask is, "Am I able to handle them?" The man who can say "Yes," *will get satisfaction*. The man who must say "No" *will be disappointed*. Each man has to decide what kind of power will best meet his requirements. If it is decided to add a tractor to the equipment to supplement the work of horses it should be chosen carefully, looked after well, and in return it will give good service.

A discussion of some phases of the power one can expect from a tractor may be of assistance to those interested in power farming. The different kinds of horsepower will now be dealt with as well as the importance of correct pulley speeds.

HORSEPOWER—WHAT IS IT?

The following incident occurred in a small prairie town in the Northwest. A farmer was in a dealer's office, where the merits of a small gasoline engine were being discussed. The dealer went so far as to tell the prospective

buyer that although it was only rated as a 1½ H.P., it could easily develop 2 H.P. At this point in the discussion the Company's blockman came in, and after the farmer had gone out the dealer was told that his line of argument was not sound and could only result in continuous trouble for the company. "Oh, well," said the dealer, "I'll make it a 2 H.P.." What did he do? He took a cold chisel and hammer and cut the two 1's from the name plate, which then read 2 H.P. in place of 1½ H.P.

That is poor business and not encouraged by reliable firms. The agents are located a long way from headquarters. If the outposts in the army fail, what then?—disaster. It is their duty, as well as the company's to give sound advice on every question that affects the problems of power on the farm. Many managers of large agencies have only hazy ideas on the subject of horsepower, but it is never too late to learn, and it is not hard to understand. There are many difficulties that come up every day just because someone is not clear about this important matter. Every farmer considering the purchase of an engine, large or small, should understand clearly the question of horsepower.

It is the purpose of this section of the bulletin to deal with some of the power problems which are facing the users of power today, and they form an ever increasing group. It is not from the viewpoint of the engineer, but from that of the average man that the term Horsepower will be discussed. It will be explained in as simple and as practical a manner as possible.

Much is written about power in a technical way, and on the other hand, it is often discussed without sufficient explanation, on the assumption that the reader already has some knowledge of the subject. The discussion will follow a line between these two extremes. It will be a general study of the term Horsepower. The terms Drawbar Horsepower and Brake Horsepower will then be considered. They are closely associated with power farming in all its branches. First, what is Work? and second, what is Power? The two terms must not be confused.

It is found on referring to a text book on mechanics that "the amount of work done depends solely upon the product of the force applied (or the resistance overcome), and the distance through which it acts," or Work=Force×Distance.

Unit of Work.

The unit of work is the work done in overcoming unit force through unit distance. Now, since the unit of force is the pound, and the unit of distance is the foot, therefore the unit of work is called the *Foot pound*. It is the work done when a resistance of one pound is overcome through a distance of one foot. By way of illustration, suppose that a block of wood lies on the table. A spring balance is attached and the block pulled through a distance of one foot. Then, if the pull registered on the balance

equals one pound, the work done equals one pound times one foot, which equals one foot pound. (Refer to upper section Fig. 18.)

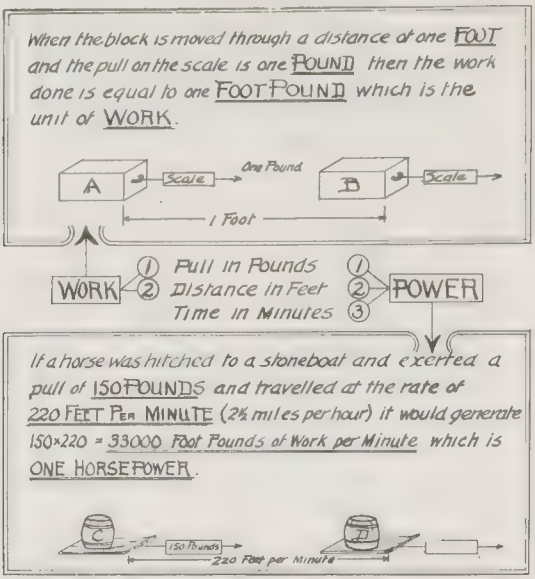

When the block is moved through a distance of one FOOT
and the pull on the scale is one POUND then the work
done is equal to one FOOT POUND which is the
unit of WORK.
A
Scale
One Pound
B
Scale
1 Foot
WORK
1 Pull in Pounds
2 Distance in Feet
Time in Minutes
1
2
3
POWER
If a horse was hitched to a stoneboat and exerted a
pull of 150 POUNDS and travelled at the rate of
220 FEET PER MINUTE (2½ miles per hour) it would generate
150×220 = 33000 Foot Pounds of Work per Minute which is
ONE HORSE POWER.
C
150 Pounds
220 Feet per Minute
D

Fig. 18.

Again, if the pull exerted on the scale equals 5 pounds and the block is pulled through a distance of 10 feet, the work done would equal 5 lbs. $\times$10 ft.=50 foot pounds.

If the pull on the scale is 10 pounds and the distance through which the block is pulled is 5 feet, the work done equals:–10 lbs.$\times$5 ft.=50 foot pounds. The result is the same in both cases. It is necessary to clearly understand this fundamental fact because everything that will follow depends upon the foregoing.

The relationship is readily seen between the two terms foot and pound, and the resulting foot pound. The answer was the same in both cases. They were considered with a straight pull in a horizontal direction, and will be referred to again in considering drawbar horsepower. Figure 19 is similar, but deals with a circle, which comes into our discussion of brake horsepower. A circle one foot in diameter has a circumference of $3\frac{1}{7}$ feet (measurement around it.) Some text books give a formula for finding the circumference of a circle in which the Greek Letter π (pronounced Pi) is used. It means 3 1 7 or 22÷7 or 3.1416. This explains the origin of the

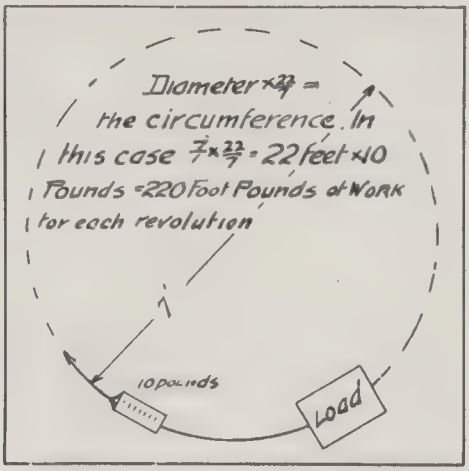


Fig. 19.

3 1/7, and to those who can already find the circumference of a circle we do not wish to teach any new way.

A circle 7 feet in diameter will have a circumference equal to $\frac{22}{7}\times 7=$ 22 feet, and for every time around this circle with a pull of 10 pounds on the scale we have 10 pounds×22 feet=220 foot pounds.

So much for the horizontal pull, either in a straight line or round in a circle. What about lifting in a vertical direction? By referring to Fig. 20 it will be seen that when a sack weighing 100 pounds is lifted a distance of 5 feet on to a platform, that 100 pounds×5 feet=500 foot pounds. To place the second sack on the platform requires the same number of foot pounds, so we have altogether 1,000 foot pounds of work. A mason's helper carries mortar from the ground to the third storey of a building. The same amount of work is done whether the task is performed in one hour or in five. The same applies to every illustration thus far. If the work is done in one hour more energy is consumed, more effort is put forth and more power is required.

Now it is seen that power is the rate of doing work (see lower section Fig. 18). The element of time enters into the calculation. Review and make sure that so far every point is clear.

Work involves two factors: { 1. Force in pounds. 2. Distance in feet.

Power involves three factors:
1. Force in pounds.
2. Distance in feet.
3. Time in minutes.

Speaking about one horsepower, it is found that:—"It is doing work at the rate of 33,000 foot pounds per minute." According to the problem with the sacks it will be assumed that two sacks, weighing 100 pounds each, were lifted five feet in one minute. This required 1,000 foot pounds of work per minute. Therefore, it would take 33 minutes of time to develop one horsepower of work, or 33,000 foot pounds of work per minute. A 1 H.P. engine would do this amount of work in one minute.

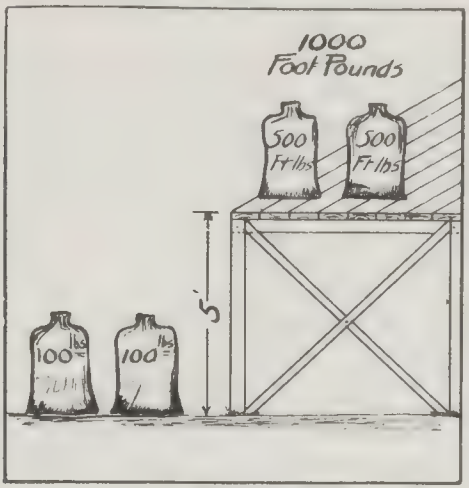


Fig. 20.

Does this term horsepower bear any relation to the work a horse can do? If so, why do some engines get stuck when horses may go right through? A very good question, asked many times. It will be answered later.

Going back 100 years to the time when coal was raised from the mines in Britain, it was found that the average horse could lift a certain number of pounds through a certain distance in one day, approximately at the rate of 33,000 foot pounds per minute. This was adopted as the standard, and it is a practical one. Take another example. A horse can pull from one-tenth to one-eighth of his weight for a period of 10 hours. Assume that a horse weighing 1,500 pounds is pulling one-tenth of his weight, or 150 pounds at the rate of 2½ miles per hour, what horsepower will he develop? Exactly one horsepower. We must find the distance in feet per minute that 2½ miles per hour represents. There are 5,280 feet in a mile and 60 minutes in an hour:—

Then: $\frac{\text{5280 (feet per mile)} \times 2\frac{1}{2} \text{ (miles per hour)}}{\text{60 (minutes in 1 hour)}} = 220 \text{ feet per minute.}$

and $\frac{\text{150 (1/10 of its weight in lbs.)} \times \text{220 (ft. per min.)}}{\text{33,000 (foot pounds of work per min. in H.P.)}} = 1 \text{ Horsepower.}$

If he travelled only 2 miles per hour he would cover $\frac{5{,}280}{60} \times 2 =$ 176 feet per minute.

$$\text{so that } \frac{150 \times 176}{33{,}000} = \frac{4}{5} \text{H.P.}$$

Consequently to develop one horsepower at the slower speed he must pull a larger load, or he might travel faster and pull a lighter load.

To sum up, it has been found out that moving a load through a certain distance (it may be along the ground in a straight line, in a circle, or up and down) requires a pull in pounds, and multiplying this by the distance in feet, gives the total number of foot pounds of work. But whenever we mention horsepower it means that the 33,000 foot pounds of work must be done in one minute.

METHOD OF DETERMINING BRAKE HORSEPOWER.

Some prefer to call it belt rather than brake horsepower. An operator ought to know what horsepower the engine is capable of developing for use at the belt. For the smaller engines the prony brake is used. This device is made of blocks of wood with a piece cut out to fit the flywheel, and these blocks are bolted to a piece of belting by small stove bolts. The heads of the bolts are countersunk on the side next to the flywheel. By referring to the illustrations it will be easily seen how the brake is applied and the necessary amount of friction secured. Fig. 21 shows how the brake is applied; Fig. 22 shows another method. In the latter case it will be noticed that a cut has been taken from a manufacturer's catalogue and the brake applied with which we are going to measure the number of foot pounds of work per minute delivered to the belt. It will be seen what is meant by the foot pound by referring to page 11.

The formula is:

$$\text{Brake horsepower} = \frac{2\pi R \times L \times N}{33{,}000}$$

$2\pi R$ equals the circumference of a circle, the radius of which is equal to the length of the brake arm, which is R. L equals the net load registered on the scale, and N equals the number of revolutions per minute.

If the engine were set on the edge of a table and the brake applied, what would happen? The brake would swing around with every turn of the flywheel. In Fig. 21 this would mean that the point at which the scale is attached would travel through a circle which had a radius equal to 3½ feet (the length of the brake arm). However, to prevent this a spring balance is attached and the pull in pounds is registered. For every revolution how much would this be?

The circumference equals

$$2\times\frac{22}{7}\times 3\tfrac{1}{2}=\frac{2\times 22\times 7}{1\times 7\times 2}=22 \text{ feet.}$$

Suppose the net pull on the scale is 10 pounds. Then for every revolution there are 10 pounds times 22 feet, which equals 220 foot pounds of work per revolution. Therefore, multiplying by 400 (the revolutions per minute of the engine) the total number of foot pounds of work per minute is found, and dividing by 33,000 the horsepower is determined (2.66 H.P.).

In Fig. 22 a platform scale is used. The reading on the scale will be the gross load, for, as can readily be seen there will be a reading on the scale when the engine is at rest (this applies to both cases), for which it cannot be given any credit. Therefore before the brake is applied, the tare is obtained and deducted from the gross load. The prony brake is held up by a straight edge at the point on the brake that would be plumb over the center of the wheel when it is applied to the flywheel. Let us suppose that the tare was 2 pounds. The thumb screws are turned down gradually until the engine will carry the load without reducing the rated speed. Oil must be applied to the flywheel.

What is the use of this test? One is able to make sure with very little trouble what horsepower the engine can develop. The timing can be adjusted to get the most power and find the position at which the carburetor gives the best results. If there is doubt about the engine being all it is represented to be, then it can be tried out. If it fails in the test the facts prove the case. Otherwise it is a case of only "thinking" it had not the power instead of "knowing." For testing tractors special equipment is needed.

The question of indicated horsepower has been purposely omitted, because the only way in which this can be ascertained is by means of an instrument called the indicator. Outside of a technical institution or the experimental department of the factory, one is seldom seen. The writer has endeavored to point out why it is important for every dealer and purchaser to understand what is meant by horsepower, in so far as it affects his power problems, and it is hoped that those who had not given the subject much thought before will follow it up.

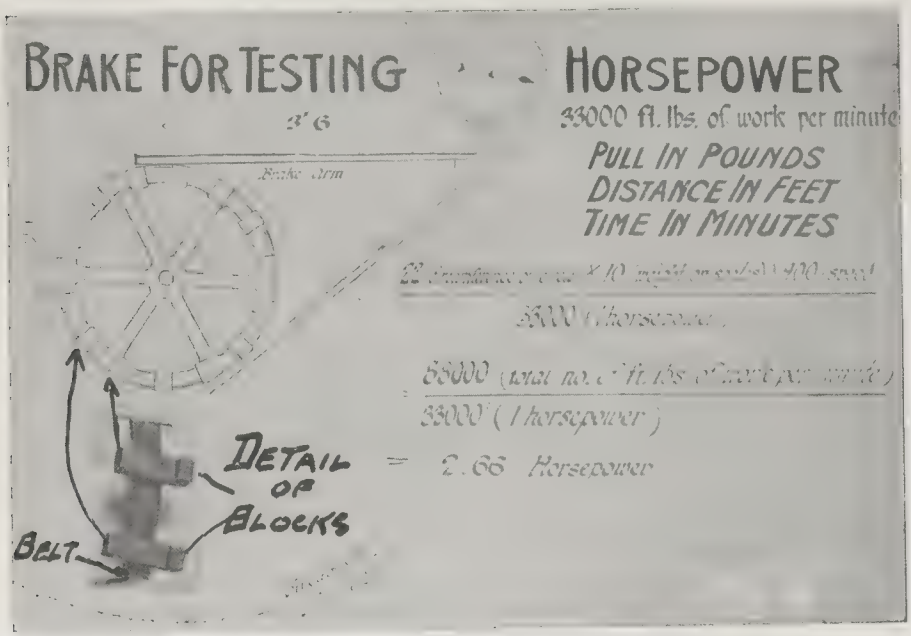

BRAKE FOR TESTING
HORSEPOWER
33000 ft. lbs. of work per minute
PULL IN POUNDS
DISTANCE IN FEET
TIME IN MINUTES
Brake Arm
DETAIL OF BLOCKS
BELT
33000 (1 horsepower)
= 2.66 Horsepower

Fig. 21

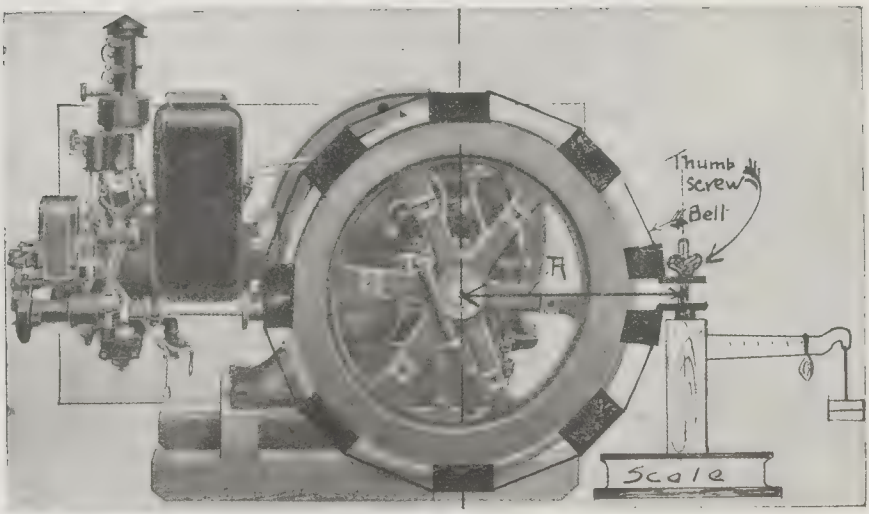

Thumb screw
Bell
Scale

Fig. 22.

DRAWBAR HORSEPOWER—WHAT IT MEANS.

A tractor is rated as a 15-30, meaning that it has a drawbar pull of 15 H.P. and will develop 30 H.P. on the belt. The main difference between horses and the tractor is that the horses can exert a pull of 15 H.P. for 10 hours, and more for short periods when they come to a tough spot in plowing or a grade on the road, while the tractor can develop 15 H.P. for 24 hours a day, every day in the week if required, but it has less reserve for the tough spots and the grades. Tractors are rated approximately to their capacity. Steam engines used to be under-rated and consequently were seldom lacking in power. However, it is well to bear in mind that the modern tractor is more economical in the use of fuel, more efficient in the transmission of power, lighter in weight per horsepower developed and faster in rate of travel, than was the case some years ago.

The tractor must be used reasonably, not solely with the idea of sticking it, as many operators try to do. Constant overloading means a short-lived machine. That fact must be impressed upon the minds of power farmers. If the engine is guaranteed to pull a two-furrow plow, a third plow should not be attached, if it means working the engine very hard all the time. With the two plows it will have enough reserve for the tough places.

An engine is rated as 15-30 H.P., meaning it has 15 H.P. at the drawbar and 30 H.P. at the belt pulley. If the tractor has only a 15 H.P. motor and it requires 15 H.P. to move the machine along the ground, it can readily be seen that no power would be available at the drawbar for plowing or other work.

To tell how many horsepower an engine is developing one must know the number of pounds it is pulling and the speed at which it is travelling in feet per minute. The number of plows tells very little. A 30 H.P. tractor has been seen pulling eight plows and within a short distance the same size of engine pulling only four plows. The difference was mostly due to the soil, which in the first case was light sand and in the second a heavy gumbo. The setting and condition of the plows had also something to do with the second case. It is possible in both cases for the tractors to be pulling the required load to give their rated horsepower on the drawbar.

The pull is tested by means of a dynamometer, a strong spring balance (see Fig. 23, which shows one type). The one shown as well as other types have been used at some of the tractor demonstrations held in the past. When the pull is known, and also the speed at which the engine is travelling, the drawbar horsepower can immediately be determined. On the other hand, if a tractor is guaranteed to pull 2,000 pounds at a speed of 2¾ miles per hour the drawbar horsepower is readily calculated. The distance in

$$\text{feet per minute will equal} \frac{5280 \times 11}{60 \times 4} = 242 \text{ feet per minute.}$$

$$\text{Then: } \frac{2000 \text{ (lbs.)} \times 242 \text{ (feet per minute)}}{33{,}000 \text{ (1 H.P.)}} = 14\ 2/3 \text{ D.B.H.P.}$$

Another tractor is guaranteed to pull 2,000 pounds at 3 miles per hour. What drawbar horsepower is developed? We shall work this problem in one step instead of two.

$$\frac{2000 \text{ (pull in pounds)} \times 264 \text{ (feet per min.)}}{33{,}000 \text{ (1 H.P.)}} = 16 \text{ D.B.H.P.}$$

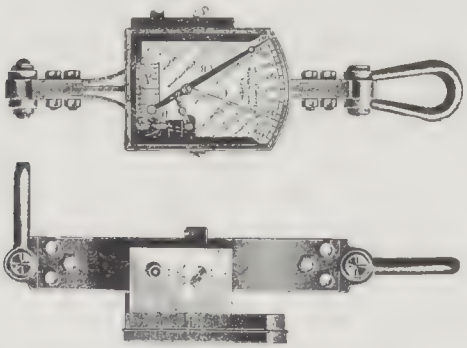


Fig. 23.

It is practically impossible to tell how many plows a tractor can pull, but as any reliable manufacturer will guarantee a definite drawbar pull at a certain speed, it is up to the owner or operator to understand the relationship between the pull, the speed, and the rated horsepower of the tractor, and the work which it may be expected to do when it leaves the warehouse and falls into the hands of the farmer.

It may be working in a light, sandy soil or heavy clay. It may be in a level or hilly country. All factors must be considered.

For example, suppose there is an engine rated as 25 H.P. at the drawbar. The operator wants to know how many plows it can pull at 2 miles per hour, it being assumed that each plow takes 750 pounds pull. Since 1 H.P. equals 33,000 foot pounds of work per minute, 25 H.P. must equal 33,000× 25, or 825,000 foot pounds of work per minute available at the drawbar. Now, 2 M.P.H. equals 176 feet per minute, so that each plow will require 750×176, or 132,000 foot pounds of work per minute. Now, if we divide 825,000 by 132,000 our answer will be the number of plows, in this case six. This is an approximate answer, but it very clearly shows what factors decide how many plows an engine can pull. The kind of soil and also the speed each enter into the final result.

A cut of a small dynamometer (see Fig. 24) suitable for horse-drawn implements also is shown.

Fig. 24.

It was found that in summer-fallowing good loam soil with a 14-inch gang plow working 8 inches deep, a pull of 1,000 to 1,100 pounds was exerted. Five large horses were used, which meant a pull of 200 pounds per horse, about one-eighth of its weight. Let us suppose they travelled 2 M.P.H., then:

$$\frac{1000 \text{ (lbs.)} \times 176 \text{ (ft. per min.)}}{33{,}000 \text{ (1 H.P.)}} = 5\ 1/3 \text{ H.P.}$$

The problem is the same with either tractor or horse, and it can readily be seen that the term Horsepower is a very practical one.

How can these things be demonstrated in the most practical way? The best opportunity at present is to make them a feature of the plowing match, agricultural fair, or small tractor demonstration in any district. A dynamometer will show exactly what pull is required by any plow at any depth. This is worth knowing. If a man were thinking of buying a tractor and knew how much was required to pull a plow in the vicinity, it would help in choosing the proper plow for a tractor of a known drawbar horsepower. A thorough understanding of this subject will help to solve many problems that are now engaging the attention of practical men.

The Nebraska Tractor Tests have been accepted as official and it is well to understand the reports that are issued and be able to interpret them. Other factors enter into the selection of a tractor, but the results of these tests are of great importance. They were started in 1920 and there is no doubt that many improvements on tractors have resulted from them.

It is important in any specific tractor report to pay more attention to the power developed in the "rated load test" than in the "maximum load test." The latter is important, but one cannot expect any tractor to work continuously on a maximum load. If power is required to this extent then a larger power unit should be selected.

Let us take an example: Tractor A is rated under the tractor rating codes of the A.S.A.E. and the S.A.E. as a 19.69—31.31 (19.69 H.P. on the drawbar and 31.31 on the belt). In the rated load test it developed 31.62 H.P. This is a satisfactory result. In the maximum load test it developed 33.26 H.P. This shows some reserve power for emergencies. In the rated load test on the drawbar it developed 20.23 H.P. In doing so it pulled 2008 pounds at 3.78 miles per hour. (Refer to explanations of drawbar horsepower on page 17.) In the maximum load test on the drawbar it developed from 22.71 H.P. to 24.29 H.P., depending on the load and the speed. These results show a good reserve. Reports of all tractors are available and should be carefully examined by those interested. So much for the power developed.

Fuel consumption is stated in terms of horsepower hours per gallon. (Referring to the American gallon of 233 cubic inches, the British Imperial gallon contains 277 cubic inches). Fuel consumption is also stated in terms of pounds of fuel per horsepower hour.

A one horsepower engine developing its rated load for one hour would develop 1 horsepower hour; if it continued to run 10 hours it would have developed 10 horsepower hours of work. A tractor developing 30 horsepower for one hour would develop 30 horsepower hours of work.

These results considered in connection with the standing of the company, the type of dealer and the ability of both to render service when justified and repairs when needed are very important.

SPEEDS OF PULLEYS

When a feed grinder is equipped with a pulley and has to be connected to a lineshaft, it is important to be able to figure out the correct size of pulley to get the required speed on the grinder. An easy way will be shown. It may save time and trouble. The number of questions that come to us on problems of this kind convinces us that to many it is a very perplexing one.

When an order is sent away for a pulley, it won't do to guess the size, *one must know*. It is important that an operator be able to figure pulley sizes correctly, otherwise delay and dissatisfaction are sure to result. For these reasons it is felt that the subject is worth discussing in some detail, because every year finds more farmers involved in power problems. It may be a washing machine or a cream separator for the women folk; it may be a threshing machine, pump, or a fanning mill for the man; or a complete power house that will help everybody. The object in all cases is to save labor and to do more efficient work. Certain pulleys have to be purchased. They must be the correct size if the machines are to run at the correct speeds. The manufacturer's advice in this respect should be closely followed.

Fig. 13 shows a diagrammatic view of a power problem. It consists of an engine driving a lineshaft which in turn is driving a feed grinder, a dynamo in connection with a farm lighting plant, a cream separator and a grindstone. The ladies may wonder where the washing machine and the churn are. Well, they were considered, and only the limited space at our disposal prevented them from being in the line. However, the problem concerning them can be solved in exactly the same way as the others. To make each step as easy as possible, the lineshaft problem is divided into five sections, and each will be dealt with in turn.

At this stage the reader should refer to Fig. 14, where the rule by which the size of any pulley can be found. The rule is: The diameter of the driver multiplied by its revolutions per minute always equals the diameter of the driven pulley multiplied by its revolutions per minute. This is expressed briefly as:—

$$D \times R.P.M. = D \times R.P.M.$$

Knowing any three of these factors the fourth can always be found. It is evident that for one revolution of the 7 inch pulley, the 3½ inch pulley must make two revolutions. Assuming 100 revolutions per minute and following the above rule it is seen that:

$$7 \times 100 = 3\tfrac{1}{2} \times 200$$
$$700 = 700$$

There is no need to look for anything mysterious or difficult. It cannot be found. It is a case of simple multiplication and division; nothing more is necessary. Now return to Fig. 13 and consider the individual problems.

THE SIZES AND SPEEDS OF PULLEYS

Fig. 13 shows a diagrammatic view of a power problem. To make each step as easy as possible the lineshaft problem has been divided into five sections and each is dealt with in turn.

Problem 1. There is an engine which runs 400 R.P.M. and it is equipped with a 12 inch pulley. The lineshaft has to run at 240 R.P.M. What size of pulley will be required?

Putting down our rule and substituting the known items:—

$$D \times R.P.M. = D \times R.P.M.$$
$$12'' \times 400 = D \times 240$$
$$\frac{4800}{240} = D$$

Diameter of pulley for the lineshaft=20 *inches.*

Problem 2. A feed grinder is equipped with a 6-inch pulley and is supposed to run 960 R.P.M. What size of pulley will be required for the

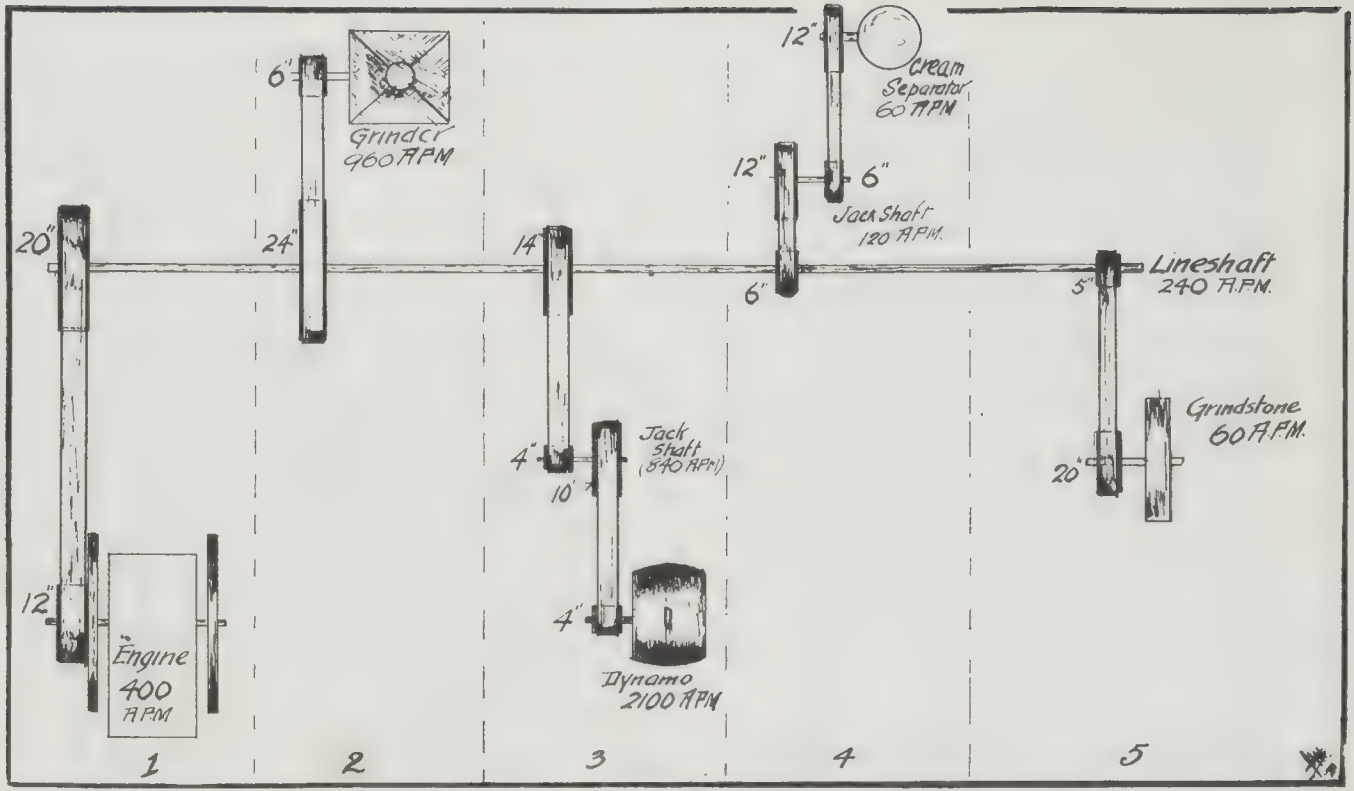


Fig. 13.

General plan showing an engine running a lineshaft. On the lineshaft are pulleys of different sizes which drive the various machines at their correct speeds.

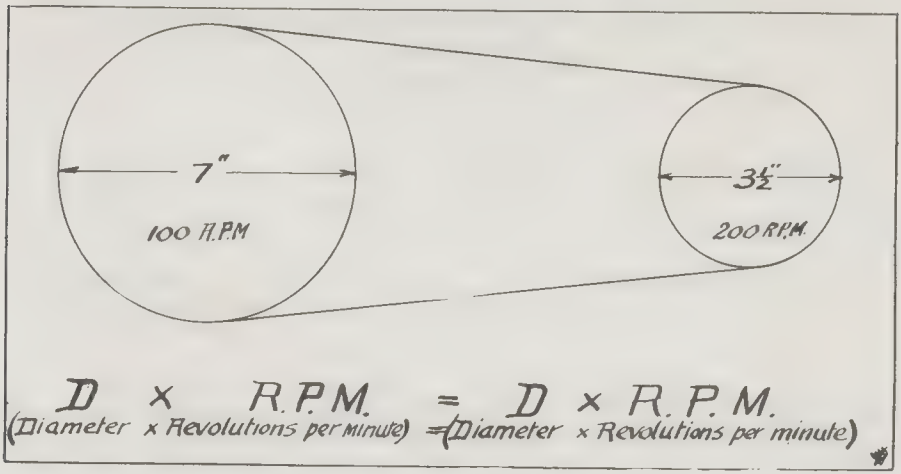


Fig. 14.

lineshaft, which will have the same speed of 240 R.P.M.? Again the problem is solved as follows:—

$$D \times R.P.M. = D \times R.P.M.$$
$$D \times 240 = 6 \times 960$$
$$D = \frac{5760}{240}$$

The size of pulley for the lineshaft=24 inches.

One always knows the size and speed of one pulley and either the size or speed of the other. Multiply the things known about the one pulley together, and divide the answer by the one thing known about the other pulley. There is not a pulley problem that cannot be solved if this simple rule is understood.

Value of Jackshaft for Stepping Up or Down.

Here is a machine that has to be driven at a high speed, and instead of having a very large pulley driving and a very small driven one (Fig. 15), the increase in speed is gained in a much better way by using a jackshaft (Fig. 15 centre) on which are mounted two pulleys (which must run at the same speed), as do all pulleys on a lineshaft.

Problem 3. It is assumed that a 14-inch pulley is on the lineshaft and that the "jackshaft" is equipped with 4" and 10" pulleys, the dynamo has a 4" pulley. (Fig 13.) How many R.P.M. will it run?

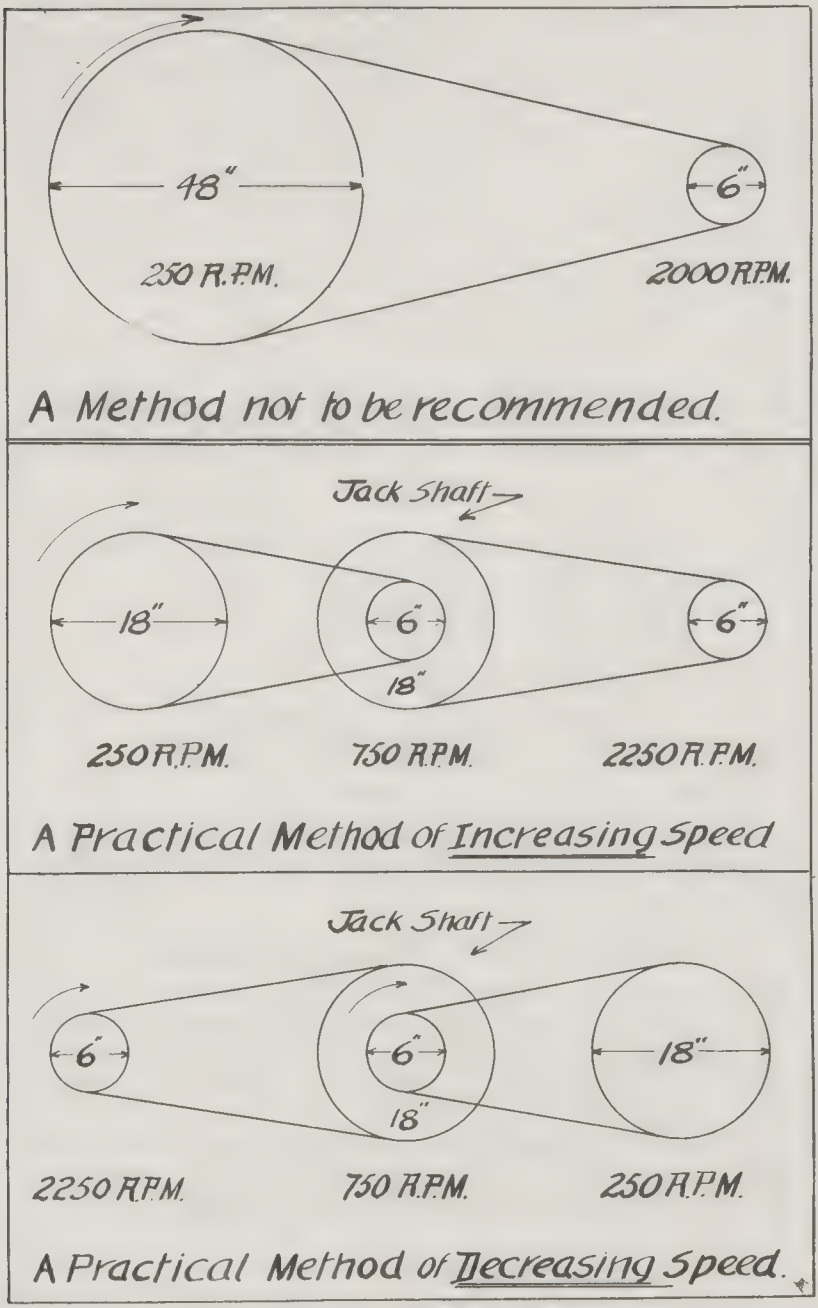

48"
6"
250 R.P.M.
2000 R.P.M.
A Method not to be recommended.
Jack Shaft
18"
6"
6"
18"
250 R.P.M.
750 R.P.M.
2250 R.P.M.
A Practical Method of Increasing Speed
Jack Shaft
6"
6"
18"
18"
2250 R.P.M.
750 R.P.M.
250 R.P.M.
A Practical Method of Decreasing Speed.

Fig. 15.

First of all get the speed of the jackshaft as before:—

$$D \times R.P.M. = D \times R.P.M.$$
$$14 \times 240 = 4 \times R\ P.M.$$
$$\frac{3360}{4} = R.P.M.$$

Revolutions of the jackshaft=840.

Then:—

$$D \times R.P.M. = D \times R.P.M.$$
$$10 \times 840 = 4 \times R.P.M.$$
$$\frac{8400}{4} = R.P.M.$$

Revolutions per minute of the dynamo=2100.

Problem 4. This is the reverse of Problem 3, namely, decreasing the speed by a jackshaft (Fig. 13). This is necessary with such machines as a fanning mill or a cream separator. The lineshaft has a 6-inch pulley and the cream separator has a 12-inch pulley which has to run 60 R.P.M. Assume that there is an extra 6-inch pulley on hand which can be made use of on the jackshaft. What size must the other pulley be for the jackshaft? The same old rule will do. Again it will take two steps; first, finding the speed of the jackshaft from the separator, and second, the size of the pulley to put on this shaft.

$$D \times R.P.M. = D \times R.P.M.$$
$$6 \times R.P.M. = 12 \times 60$$
$$R.P.M. = \frac{720}{6}$$

Revolutions per minute of jackshaft=120

Then:—

$$D \times R.P.M. = D \times R.P.M.$$
$$6 \times 240 = D \times 120$$
$$\frac{1440}{120} = D$$

Diameter of larger pulley on jackshaft=12 *inches.*

Problem 5. The grindstone came from the jobbing house with a 20-inch pulley, and the instruction book said that it should run 60 revolutions per minute. What size of pulley must be purchased for the lineshaft?

$$D \times R.P.M. = D \times R.P.M.$$
$$D \times 240 = 20 \times 60$$
$$D = \frac{1200}{240}$$

Diameter of lineshaft pulley=5 inches.

Other illustrations might be given, but enough has been said to show that similar problems can be solved very easily.

The question of surface speed or belt speed causes some confusion especially in threshing machine problems. By referring to Fig 16 we can

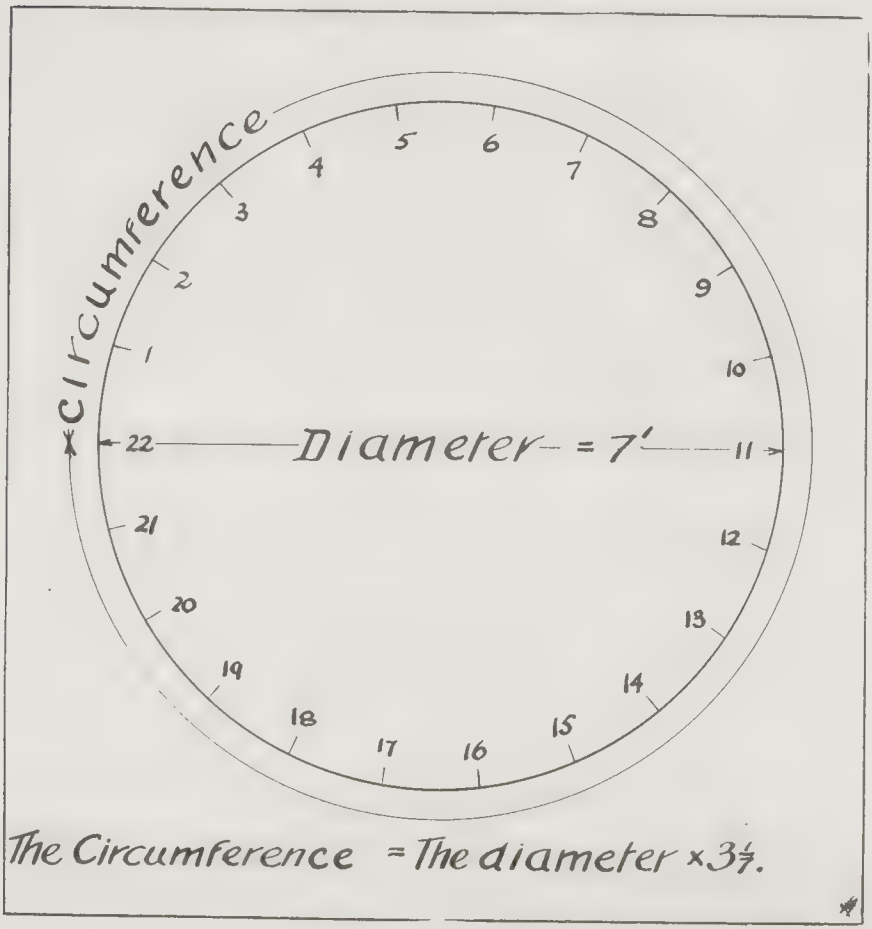


Fig. 16.

readily understand how the surface speed is determined. To find the circumference of any circle we multiply the diameter by $3\frac{1}{7}$ or $\frac{22}{7}$ ($3\frac{1}{7} = \frac{22}{7} = 3.1416$).

For example:—The circumference of a circle 7 feet in diameter equals 7×3 1/7, or 22 feet. This is actually laid out in the diagram. It is evident that if this point marked 1 made one complete revolution it would travel 22 feet and if it made 100 revolutions in a minute the surface speed in feet per minute would equal 2200. The circle may be a tractor wheel rolling along the ground, it may be a pulley on a shaft, it may be the cylinder on a threshing machine or an emery wheel in a machine shop; but in every case it travels through a certain number of feet per minute, which is called the surface speed. The surface speed is sometimes called rim speed or cutting speed. The terms all mean the same thing.

The question of surface speed is met with more especially in threshing machinery. Many think they know more than the manufacturer, and by not paying attention to correct pulley speeds and sizes land in trouble.

Take a definite example:—The tooth of a cylinder (surface speed) is in the neighborhood of 6200 feet per minute. That means that a 24-inch cylinder has to run 986 revolutions while a 32-inch cylinder would only have to run 740 R.P.M. The larger cylinder can run slower than the smaller one and still have the same surface speed. The pulleys on a lineshaft run the same number of revolutions per minute, but the surface speed of each may vary widely.

It is evident that because the same belt runs over two pulleys their surface speeds must be the same although the revolutions per minute may vary, the smaller one having to run faster. However, to figure the size or R.P.M. of a pulley the surface speed does not have to be considered at all. The old rule holds good. The diameter of the driver, multiplied by the revolutions per minute always equals the diameter of the driven pulley by its revolutions per minute. Fig. 17 explains itself and shows the advantage of running the belt so that the slack side is on the top.

Belt lacing is closely related to the discussion of pulley speeds, and it will be dealt with now.

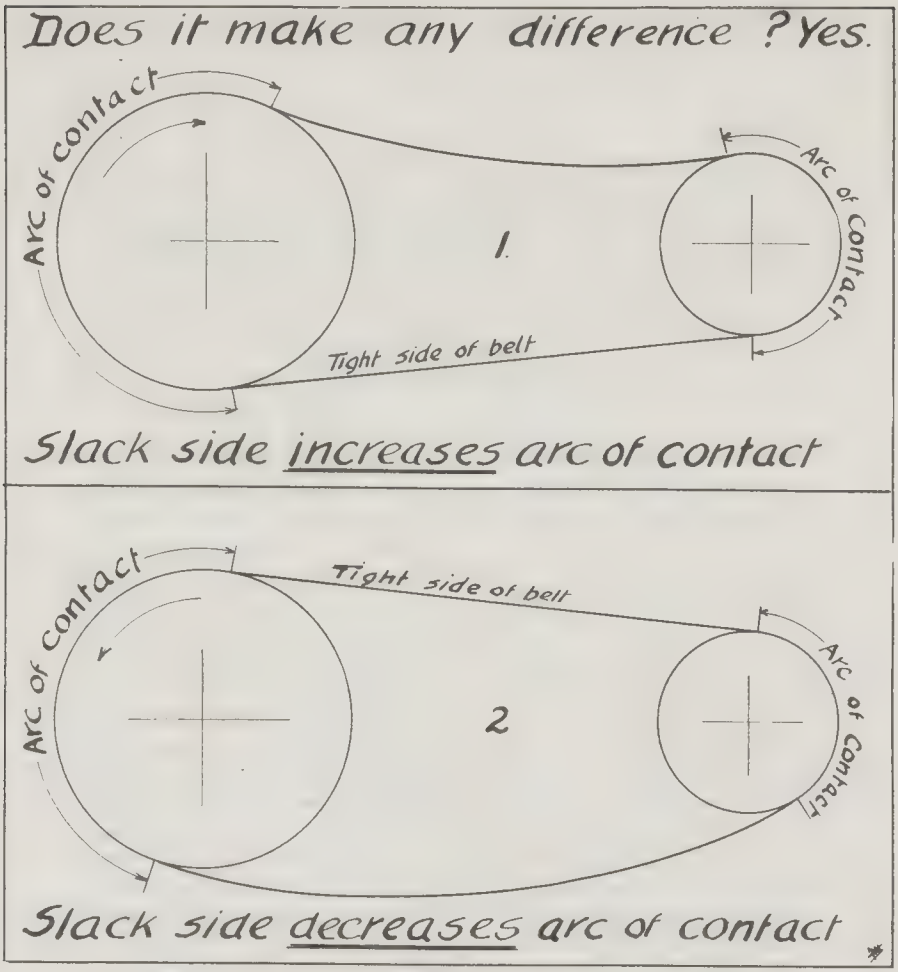


Fig. 17.

HOW TO LACE A BELT.

Every man who operates, owns or sells engines and belt machines, ought to be able to lace a belt in a workmanlike manner. Anyone operating power machinery and unable to lace a belt correctly is dependent on others and wastes much time. The owner of an engine should be able to instruct his hired help.

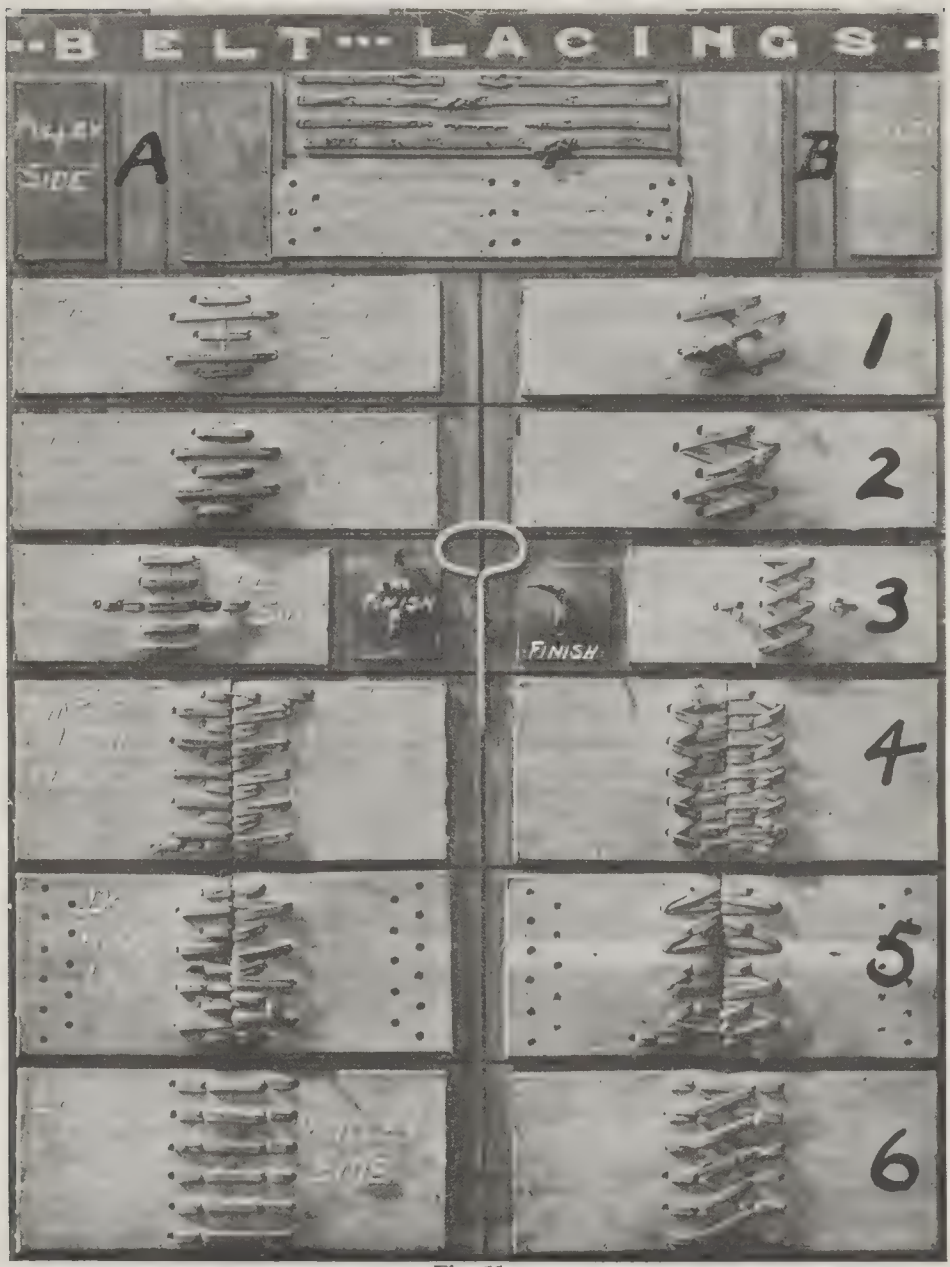


Fig. 11.

The exhibits in the upper left and right-hand corners of the above illustrations, which are marked A and B respectively, show the right side of a leather and a rubber belt to run next to the pulley. The piece of belting between A and B emphasizes the importance of cutting the ends square and of locating the holes systematically. Above this exhibit are four rows showing from the top down:

(1)—How to splice a lace by cutting a slit in the ends.

(2)—The finished splice.

(3)—A kink that saves time. Burn the end of a lace with a match. It will then be as hard as a nail and more easily pushed through the holes.

(4)—A method of finishing. It is used in lacings 1 and 2. The different styles of lacings are shown below and numbered in the order in which they are discussed in detail with the aid of the drawings.

In threshing time the entire gang gathers around the separator man when the drive belt has to be laced as if he were a wizard. He is not, and in many cases is a long way from being one. To many it seems a complicated operation. It is not. The writer has demonstrated the methods shown, in short course work with farmers as well as with agricultural students, and has found that they can be easily mastered with a little study and practice.

The reader will notice that in every case the lacing is started in the middle of the belt. By starting them all in this way the different methods are more easily remembered, and with the wide belt there is an advantage. Two men can lace at one time, the one to the right and the other to the left. Those who prefer to start at the edge and work across must be careful not to pull the lacing too tight at first, or the ends will not come together as they should.

There are many good ways of lacing belts. It is better to follow good advice and master one or two, rather than guess at them all. Two good methods to use are the hinge lace and a straight lace.

First of all, what is the problem? It is to make a smooth joint practically as strong as the belt itself. Let us discuss some general features of the work and then proceed by means of diagrams and the accompanying instructions, to make belt lacing as simple as possible to the layman who wants to learn.

When a belt has to be laced the first step is to cut the ends square, a small try-square is used for this purpose. Then the holes should be located systematically. Many separator men never have time to cut the ends square.

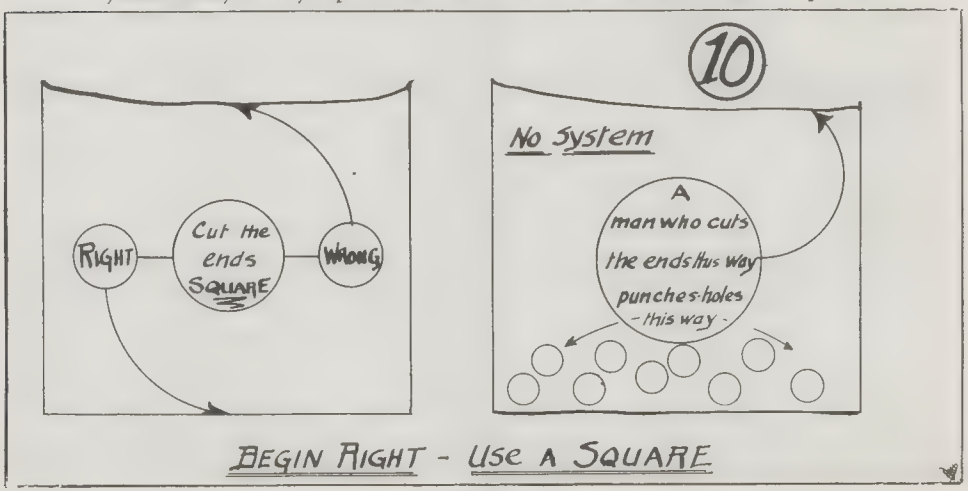
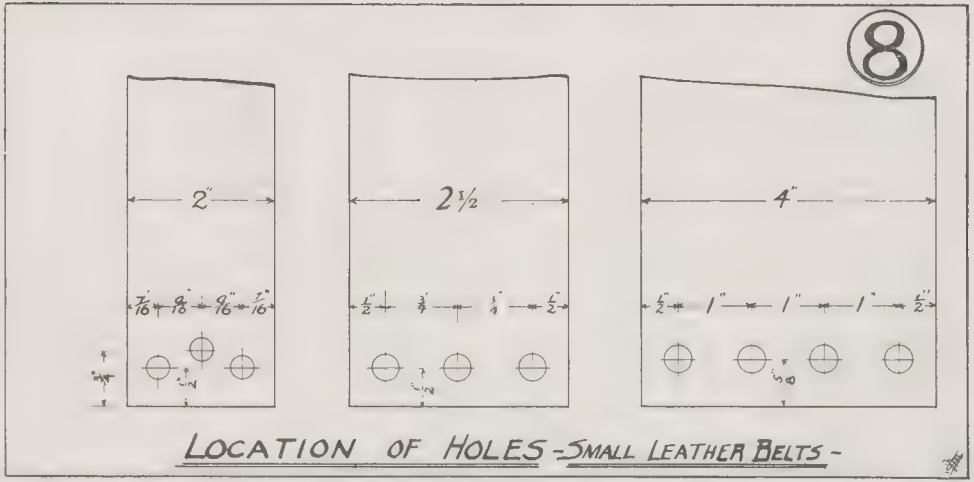
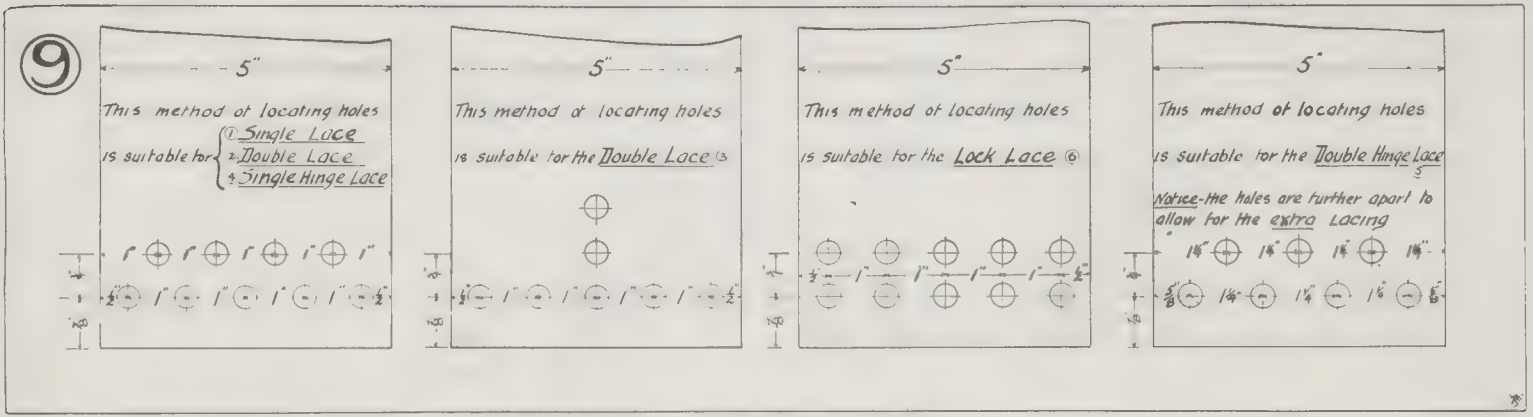


Fig. 10.




9
5"
This method of locating holes is suitable for ① Single Lace ② Double Lace ④ Single Hinge Lace
5"
This method of locating holes is suitable for the Double Lace ③
5"
This method of locating holes is suitable for the Lock Lace ⑥
5"
This method of locating holes is suitable for the Double Hinge Lace ⑤
Notice - the holes are further apart to allow for the extra Lacing

Figs. 8 and 9.

Location of holes for different lacings.

In such cases the holes are punched as shown in Fig. 10, the leather belts are running with the wrong side next to the pulley, and every belt is cracked. No one could show them anything. A good lacing should be as nearly similar to the rest of the belt as possible, so that there will be no jar as it passes over the pulleys. Too thick a lace should not be used.

Location of Holes

In leather belts the holes may be from ½ inch to ¾ of an inch from end of the belt. Fig. 8 shows how they may be located across the belt; 2, 2½ and 4 inch belts are shown. When rubber belts are used, two rows of holes should be made, as they are more likely to tear out than in a leather belt (Fig. 9). The holes should not be punched with a belt punch in rubber belts; this weakens the belt. An awl can be made from the tine of an old pitchfork (see Fig. 11). It takes more time to make the holes this way, but a better and stronger joint results.

Side Next to Pulley.

The hair side, or smooth side, of a leather belt runs next to the pulley. The side of a rubber belt with the seam should be away from the pulley. Some think that since the hide on the animal has the hair side out that it should be the same way on the pulley. This is not the case.

Details of Lacing

Single Lace—Fig. 1.

Lace "A": Goes up through hole 1, down through hole 2; up through hole 3, down through hole 4; up through hole 5, down through hole 6; up through hole 7, down through hole 8; up through hole 9A.

Lace "B": Goes up through hole 1, down through hole 2; up through hole 3, down through hole 4; up through hole 5, down through hole 6; up through hole 7, down through hole 8; up through hole 9B.

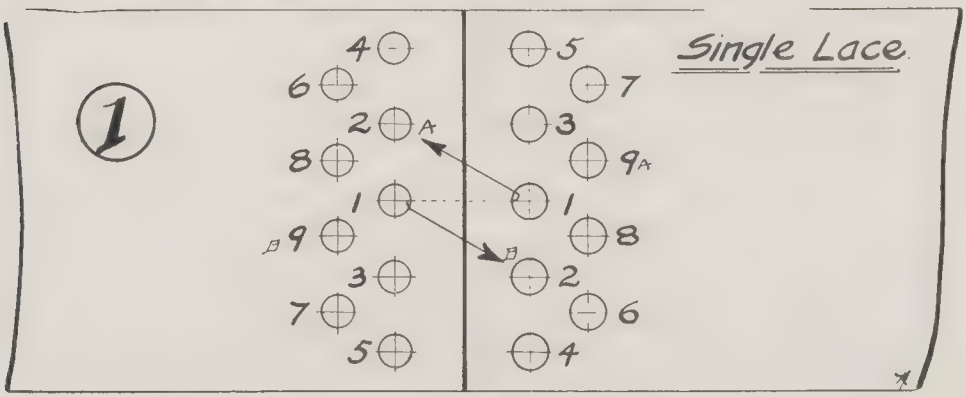


Fig. 1.

The laces meet on the side away from the pulley between the holes 9A and 9B, as shown in Fig. 1, and also in the figure where both sides of the belt are shown as well as the method of finishing.

Double Lace—First Method—Fig. 2.

Lace "A": Goes up through hole 1, down through hole 2; up through hole 3, down through hole 4; up through hole 5, down through hole 6; up through hole 7, down through hole 8; up through hole 9, down through hole 10; up through hole 11, down through hole 12; up through hole 13, down through hole 14; up through hole 15, down through hole 16; up through hole 17, down through hole 18, up through hole 19A.

Lace "B": Goes up through hole 1, down through hole 2; up through hole 3, down through hole 4; up through hole 5, down through hole 6; up through hole 7, down through hole 8; up through hole 9, down through hole 10; up through hole 11, down through hole 12, up through hole 13, down through hole 14; up through hole 15, down through hole 16; up through hole 17B.

The laces meet on the side of the belt away from the pulley between holes 19A and 17B, as shown in Fig. 2 (and also in Fig. 11), where both sides of the belt are shown as well as the method of finishing.

Double Lace—Second Method—Fig. 3.

Both lace "A" and lace "B" go as before—up through hole 1, down through hole 2; then up and down as before, up through the odd numbered holes and down through the holes with even numbers, ending with the lacing up through hole 13.

This time the laces finish as shown in Fig. 3, and in Fig. 11. When finished the lace is double except in the middle, which can be made double.

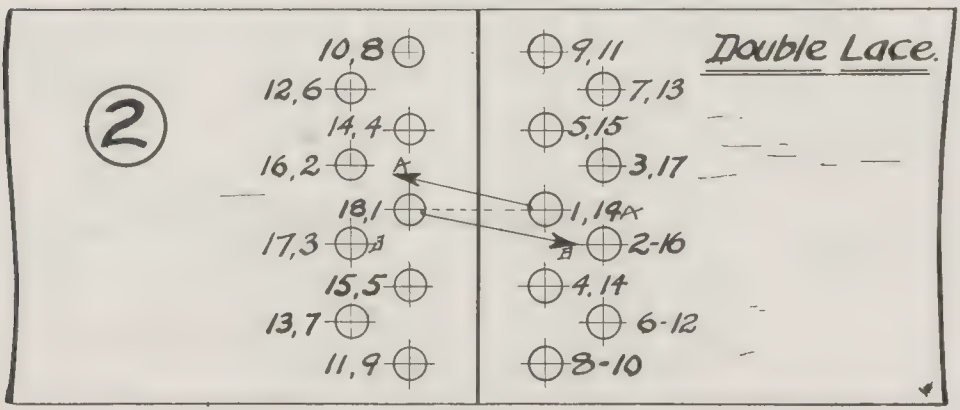


Fig. 2.

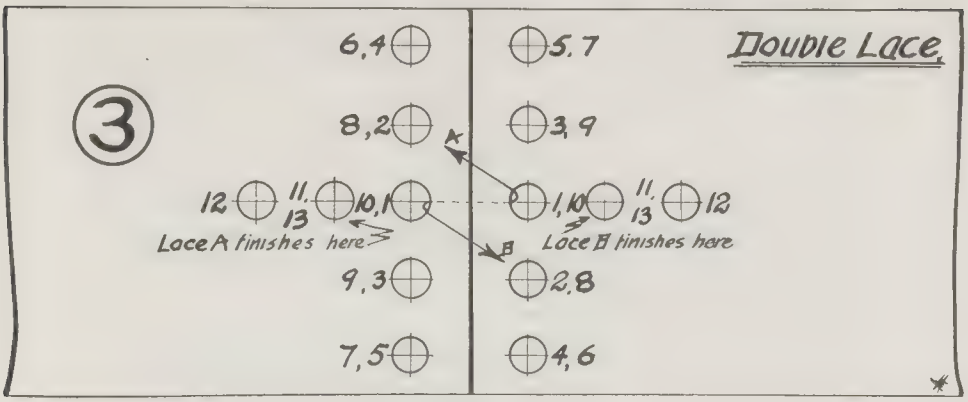


Fig. 3.

But a pulley is usually crowned and a belt finished as shown will adapt itself very well to it. The extra lace through the holes 11 and 12 helps to ease a rather thick lacing onto the pulley without much of a jar.

Hinge Lace—Fig. 4.

This lace should be used where the belt runs over a very small pulley, or when both sides of the belt come in contact with a pulley, a feeder belt, for example. In passing from one belt to the other the lace has to pass in between the two ends before going through the next hole. The first position is shown with the lace through 1A and 1B.

Lace "A" then goes up between the ends of the belts and down through hole 2A, then up between the ends of the belts and down through hole 3A, and so on—always up between the ends of the belts and down through the holes, ending with 9A.

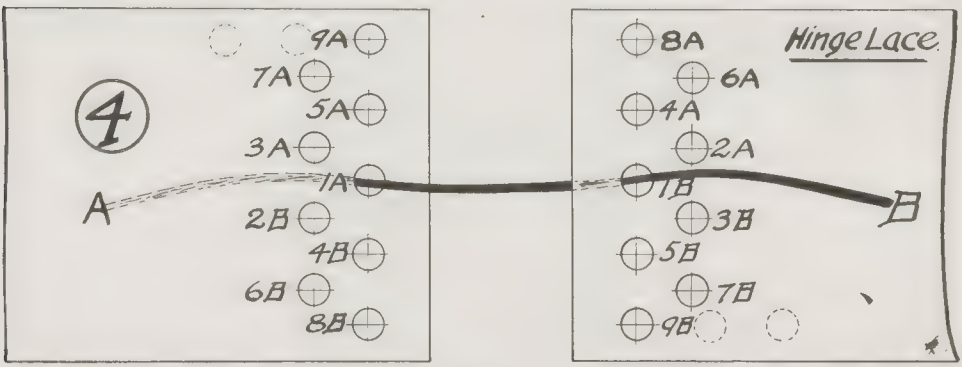


Fig. 4.

This lace can now be finished off in either of two ways: (1) By passing through the holes marked faintly behind 9A in Fig. 4, or (2) by passing from 9A through 7A, 5A, 3A, 1A, 2B, 4B, 6B, 8B, 6B, 4B, 2B, 1A, 3A, 5A, 7A and 9A (Fig. 4). This latter method is strongly in favor with practical men because the back row prevents the lace cutting so quickly.

Lace "B" starting from 1B, goes down between the ends of the belts, and up through the holes 2B to 9B, inclusive. This lace can be finished as indicated in the case of lace "A".

Double Hinge Lace—Fig. 5.

The method of making the double hinge lace is similar to that used in making the single hinge, but the lace goes through each hole twice. The first position is shown with lace through holes 1, 1.

Lace "A" goes up between the ends of the belts and down through 2A, then up between the ends of the belts and down through 3, and so on—always up between the ends of the belts and down through the holes, ending with 18, where it is finished as shown in figure 11.

This lace may be started in the middle and laced singly to the outside and back to the middle, where both ends meet. It is a very good lace for the main drive belt of a separator.

Lock Lace—Fig. 6.

The lock lace is popular. Like all of the foregoing, we start in the middle at holes, 1, 1.

Lace "A" goes up through hole 1 and down through hole 2 and so on—up through the holes with odd numbers and down through the holes with even numbers, ending with the lace up through hole 23.

Lace "B" goes the same way, starting at hole 1, going up through the holes with odd numbers and down through the holes with even numbers, ending with the lace up through hole 17.

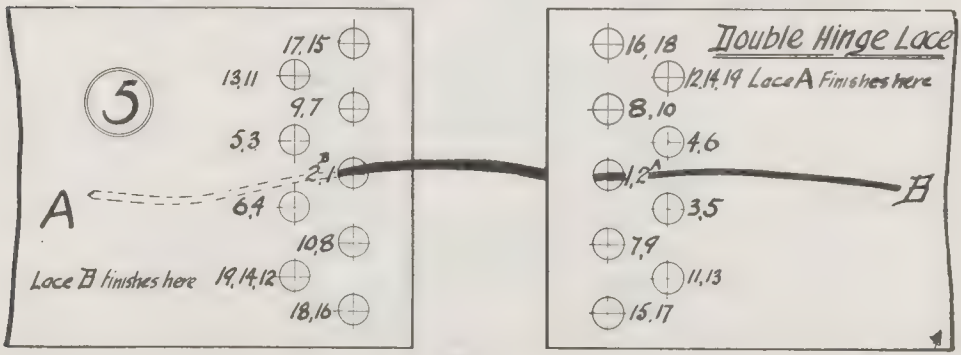


Fig. 5.

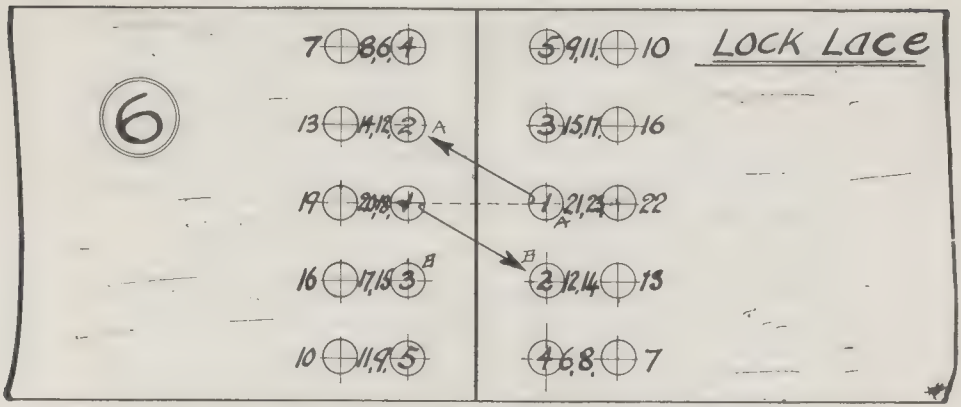


Fig. 6.

The laces meet on the side of the belt away from the pulley between the holes 17B and 23A. Fig. 7 shows another lacing.

One writer says:—The bootleg lace is used considerably, especially for rubber and cotton belts, but it must be confessed that this form lacks much popularity. It gives uniform and continuous belt contact and a good, stout twine serves for it as well as the most expensive whang leather. It is easily and quickly made and it will outlast any other lacing known. But it looks "perfectly horrid," and it is quite likely to knock a thumb off an incautious operator or spectator. This form of lacing is called 'Bootleg' not because of any relation to illicit booze selling, but because it is made exactly as the old-fashioned bootlegs were sewn up."

There are commercial belt fastenings which are good. Illustration 12 shows a common type and one that is easily applied. There is another very good kind that requires a special machine to fasten it on to the ends of the belt.

POINTS ABOUT BELTS

There are three kinds of belting—leather, rubber and canvas. Each one has special advantages, either of durability, efficiency or economy, but no one kind combines all advantages.

Under proper protection leather belting of good quality is supposed to be the most durable, but it is susceptible to deterioration from heat and moisture. For this reason, and also because of the high price of leather at the present time, other varieties of belting are in greater demand for farm work. In using leather belting it is well to remember that the grain side of the belt, that which has had the hair, should be run next to the pulleys.

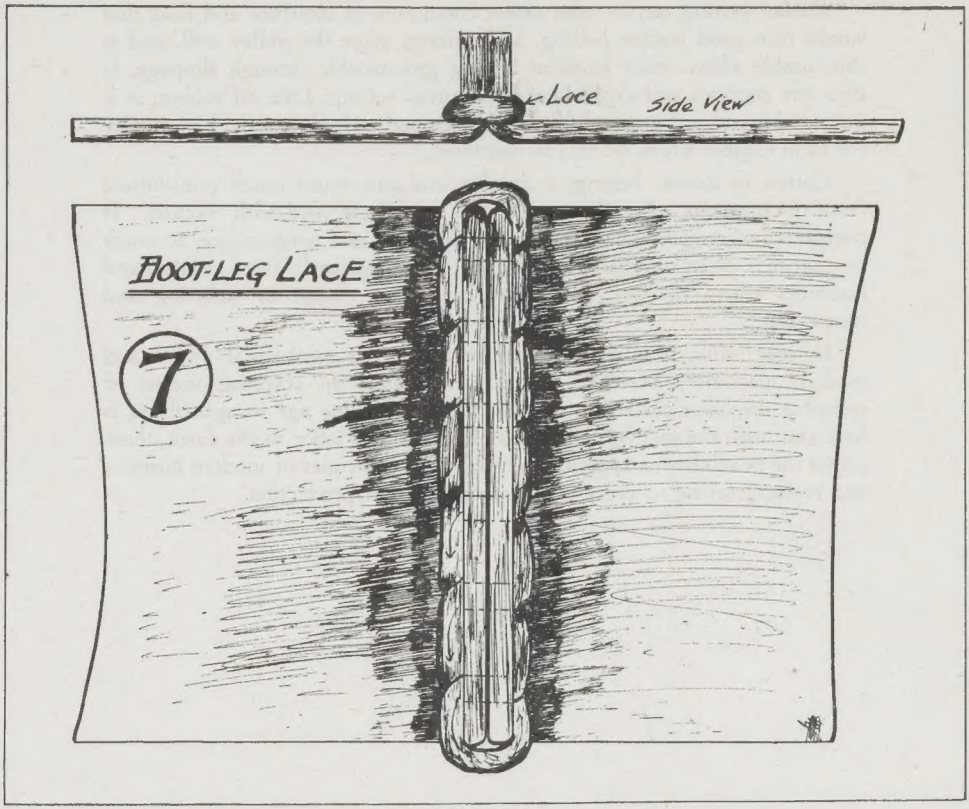


Fig. 7.

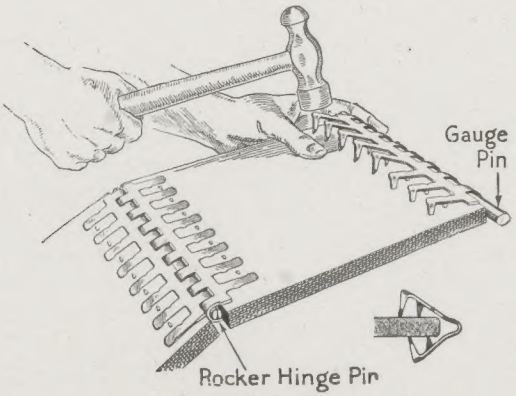


Fig. 12